104
34-m BWG Stations
Telecommunications Interfaces

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Note to Readers

There are two sets of document histories in the 810-005 document, and these histories are reflected in the header at the top of the page. First, the entire document is periodically released as a revision when major changes affect a majority of the modules. For example, this module is part of 810-005, Revision E. Second, the individual modules also change, starting as an initial issue that has no revision letter. When a module is changed, a change letter is appended to the module number on the second line of the header and a summary of the changes is entered in the module's change log.

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1 Introduction

1.1 Purpose

This module provides the performance parameters for the Deep Space Network (DSN) 34-m Beam Waveguide (BWG) antennas and the 34-m High-Speed BWG (HSB) antenna that are necessary to perform the nominal design of a telecommunications link. It also summarizes the capabilities of these antennas for mission planning purposes and for comparison with other ground station antennas.

1.2 Scope

The scope of this module is limited to providing those parameters that characterize the RF performance of the 34-meter BWG and HSB antennas, including the effects of weather that are unique to these types of antennas. Unless otherwise specified, the parameters do not include weather effects, such as reduction of system gain and increase in system noise temperature, that are common to all antenna types. These are discussed in module 105, Atmospheric and Environmental Effects. This module also does not discuss mechanical restrictions on antenna performance that are covered in module 302, Antenna Positioning.

2 General Information

The 34-meter diameter BWG and HSB antennas are the new generation of antennas being built for use in the DSN. These antennas differ from more conventional antennas (for example, the 34-meter HEF antennas; refer to module 103) in the fact that a series of small mirrors (approximately 2.5 meters diameter) direct microwave energy from the region above the main reflector to a location at the base of the antenna, typically in a pedestal room, which may be located below ground level. The pedestal room is located below the azimuth track of the antenna, although other beam-waveguide designs (not utilized by the DSN) locate the microwave equipment in an “alidade room” above the azimuth track, but below the main reflector. All antennas described in this module are of the pedestal room design.

In this configuration, numerous “stations” of microwave equipment, contained in the pedestal room, can be accessed by rotation of an ellipsoidal mirror located on the pedestal room floor. This enables great versatility of design and allows tracking using equipment at one station while equipment installation or maintenance is carried out at the other stations. Since cryogenic low-noise amplifiers (LNAs) do not tip (as they do when located in a cone or room above the elevation axis), certain state-of-the-art ultra-low-noise amplifier (ULNA) and feed designs can be implemented.

The HSB antenna differs from the BWG antennas in that the pedestal room is above ground level, the optics design is different, and the subreflector does not focus automatically for the purpose of maintaining gain as the elevation angle of the antenna changes. The HSB antenna has higher tracking rates than do the BWG antennas; thus, it is the appropriate antenna to use when tracking Earth-orbiting satellites.

The capabilities of each antenna are significantly different depending on the microwave, transmitting, and receiving equipment installed. A summary of these differences is provided in Table 1. Functional block diagrams for each antenna are provided in Figures 1–5. In general, each antenna has two LNAs for telemetry reception or radio science (although the HSB antenna only has one and DSS 25 has three). Each antenna also has at least one transmitter. Antennas with more than one transmitter can operate only one of them at a time. Once again, DSS 25 is an exception and has a Ka-band transmitter that can be operated at the same time as its X-band transmitter.

All feeds provide selectable right-circular polarization (RCP) or left-circular polarization (LCP) with the exception of the Ka-band feeds at DSS 25 that operate only with RCP. The transmitter is coupled into the microwave path using a frequency-selective diplexer. Because the diplexer increases the operating system temperature, a non-diplexed path is also provided at all antennas (except the HSB antenna) for receive-only operation.

Stations with X-band transmitters can transmit with either the same or the opposite polarization from that being received, whereas S-band transmission must be the same polarization as is being received. If the uplink and downlink are of the same polarization, reception must be through the diplexer with increased noise and lower gain than the non-diplexed path. DSS 25 and DSS 26 have two X-band LNAs and can receive simultaneous RCP and LCP (although one of the signals will be via the non-diplexed path and the other will be via the diplexed path). The two LNAs at DSS 25 and DSS 26 can also be interchanged between the diplexed and non-diplexed paths. Thus, there are four possible ways a single X-band signal can be received at these stations.

2.1 Telecommunications Parameters

The significant parameters of the 34-meter BWG and HSB antennas that influence the design of the telecommunications uplink are listed in Tables 2 through 8. Variations in these parameters, which are inherent in the design of the antennas, are discussed below. Other factors that degrade link performance are discussed in modules 105 (Atmospheric and Environmental Effects) and 106 (Solar Corona and Solar Wind Effects).

The values in these tables do not include the effects of the atmosphere. However, the attenuation and noise-temperature effects of weather for three specific weather conditions are included in the figures at the end of the module so that they may be used for a quick estimate of telecommunications link performance for those specific conditions without reference to module 105. For detailed design control table use, the more comprehensive and detailed S-, X-, and Ka-band weather effects models (for weather conditions up to 99% cumulative distribution) in module 105 should be used.

2.1.1 Antenna Gain Variation

Because the gain is referenced to the feedhorn aperture, such items as diplexers and waveguide runs to alternate LNAs that are "downstream" (below or toward the LNA) do not affect the gain at the reference plane. Dichroic plates that are "upstream" of the feedhorn aperture cause a reduction in gain.

2.1.1.1 Frequency Effects

Antenna gains are specified at the indicated frequency (f_0). For operation at higher frequencies in the same band, the gain (dBi) must be increased by 20 log (f/f_0). For operation at lower frequencies in the same band, the gain must be reduced by 20 log (f/f_0).

2.1.1.2 Elevation Angle Effects

Structural deformation causes a reduction in gain when the antenna is operated at an elevation angle other than where the reflector panels were aligned. The effective gain of the antenna also is reduced by atmospheric attenuation, which is a function of elevation. Figures 6 through 11 show representative curves of gain versus elevation angle for selected stations and configurations. The curves show the hypothetical vacuum (no atmosphere) condition and the gain with 0%, 50%, and 90% weather conditions, designated as CD (cumulative distribution) = 0.00, 0.50, and 0.90. 0% means minimum weather effect (exceeded 100% of the time); 90% means that effect which is exceeded only 10% of the time. Qualitatively, 0% corresponds to the driest condition of the atmosphere; 25% corresponds to average clear; 50% corresponds to humid or very light clouds; and 90% corresponds to very cloudy, but with no rain. Appendix A provides the complete set of parameters from which these curves were created. These parameters, in combination with the weather-effects parameters from module 105, can be used to calculate the gain versus elevation angle curve for any antenna, in any configuration, for weather conditions up to 99% CD.

2.1.1.3 Wind Loading

The gain reduction at X-band due to wind loading is listed in Table 9. The tabular data are for structural deformation only and presume that the antenna is maintained on-point by conical scan (CONSCAN) or Monopulse, discussed in module 302, Antenna Positioning. In addition to structural deformation, wind introduces a pointing error, which is related to the antenna elevation angle, the angle between the antenna and the wind, and the wind speed. The effects of pointing error are discussed below. Cumulative probability distributions of wind velocity at Goldstone are given in module 105.

2.1.2 System Noise Temperature Variation

The operating system temperature (T_{op}) varies as a function of elevation angle due to changes in the path length through the atmosphere and ground noise received by the sidelobe pattern of the antenna. Figures 12 through 17 show the combined effects of these factors for the same set of stations and configurations selected above. The figures show the hypothetical vacuum and the 0%, 50%, and 90% weather conditions. The equations and parameters for these curves are provided in Appendix A and can be used, in combination with the weather-effects parameters from module 105, to calculate the system temperature versus elevation curve for any antenna, in any configuration, for weather conditions up to 99% CD.

When two LNAs are available for use, the amplifier in the lowest loss (lowest noise) configuration is considered prime and is designated LNA-1. Under some conditions, LNA-2 may be used; in these instances, the higher noise-temperature values apply.

The system temperature values in Tables 6–8 do not include any atmospheric contribution and must be increased for comparison with antennas that are specified with 25% weather. Table 10 provides adjustments to the hypothetical no-atmosphere (vacuum) operating system temperature ($T_{op,\ vac}$) that were calculated using the weather models in module 105.

2.1.3 Antenna Pointing

2.1.3.1 Pointing Accuracy

The pointing accuracy of an antenna, often referred to as its *blind-pointing* performance, is the difference between the calculated beam direction and the actual beam direction. The error is random and can be divided into two major categories. The first of these includes the computational errors and uncertainties associated with the radio sources used to calibrate the antenna and the location of the spacecraft provided by its navigation team. The second has many components associated with converting a calculated beam direction to the physical positioning of a large mechanical structure. Included are such things as atmospheric instability, servo and encoder errors, thermally and gravitationally induced structural deformation, azimuth track leveling (for an azimuth-elevation antenna), and both seismic and diurnal ground tilt.

Blind pointing is modeled by assuming equal pointing performance in the elevation (EL) and cross-elevation (X-EL) directions. That is, the random pointing errors in each direction have uncorrelated Gaussian distributions with the same standard deviation. This results in a Rayleigh distribution for pointing error where the mean radial error is 1.253 times the standard deviation of the EL and X-EL components. For a Rayleigh distribution, the probability that the pointing error will be less than the mean radial error is 54.4%. Conversely, the probability that the mean radial error will be exceeded is 45.6%.

Table 11 provides the modeled blind-pointing performance and the resulting gain reductions in various wind conditions for the BWG antennas. In addition to the mean radial error (CD = 54.4%), pointing errors for the 90%, 95%, and 99% points on the Rayleigh distribution curve are also provided. A CD of 90% implies that 90% of the time, the pointing error or pointing loss will be less than the value shown, and so forth.

2.1.3.2 Pointing Loss

Figures 18 through 20 show the effects of pointing error on effective transmit and receive gain of the antenna. These curves are Gaussian approximations based on measured and predicted antenna beamwidths. Data have been normalized to eliminate elevation and wind-loading effects. The equations used to derive the curves are provided in Appendix A.

2.1.3.3 Ka-Band Aberration Correction

The extremely narrow beamwidth at Ka-band requires that a Ka-band uplink signal be aimed at where the spacecraft will be when the signal arrives, while simultaneously receiving a signal that left the spacecraft one light-time previously. This is accomplished by mounting the Ka-band transmit feed on a movable X-Y platform that can displace the transmitted beam as much as 30 millidegrees from the received beam. The fact that the transmit feed is displaced from its optimum focus causes the gain reduction depicted in Figure 21. The equation used to generate this curve is provided in Appendix A.

2.2 Recommended Minimum Operating Carrier Signal Levels

Table 12 provides the recommended minimum operating carrier-signal levels for selected values of receiver tracking-loop bandwidth (B_l) when using the Block V Receiver (BVR). These levels provide a signal-to-noise ratio of 10 dB in the carrier tracking loop, based on the nominal zenith system temperatures given in Tables 5–8 adjusted for an average clear atmosphere, CD=0.25. Use of loop bandwidths less than 1 Hz are not recommended for the HSB antenna due to phase noise introduced by its long distance (approximately 30 km) between the antenna and its BVR.

The HSB antenna has an additional receiver, the Multifunction Receiver (MFR), that provides wider loop bandwidths for high-Doppler Earth-orbiter spacecraft. The recommended minimum operating carrier signal levels for the available MFR tracking loop bandwidths are provided in Table 13. These values also provide a tracking loop signal-to-noise ratio of 10 dB based on the nominal zenith system temperature given in Table 8 and an average clear atmosphere.

3 Proposed Capabilities

The following paragraphs discuss capabilities that have not yet been implemented by the DSN but have adequate maturity to be considered for spacecraft mission and equipment design. Telecommunications engineers are advised that any capabilities discussed in this section cannot be committed to except by negotiation with the Telecommunications and Mission Operations Directorate (TMOD) Plans and Commitments Program Office.

3.1 34-m BWG Ka-Band Implementation

All DSN BWG antennas except DSS 27 are being equipped with a Ka-band receive-only capability by replacing the existing X-band feed and microwave components with an X/X/Ka-band feed that includes the X-band diplexing function. The 34-m BWG Ka-band implementation will eliminate the need to run transmitted power through the feed's receive port and allows the entire receive portion to be cryogenically cooled.

3.1.1 X-Band Uplink Performance

The X-band uplink performance will be as described in Table 4 (with the exception of X-band effective isotropic radiated power [EIRP] that may be reduced approximately 0.1 dB due to increased loss in the waveguide that couples the transmitter to the feed). An X-band transmitter will be added to DSS 24 so that all BWG antennas (except DSS 27) will have X-band uplink and simultaneous X- and Ka-band downlink capability.

3.1.2 X-Band Downlink Performance

The combination of the cryogenically cooled feed, better amplifiers, and reduced microwave complexity is expected to provide a peak vacuum gain over temperature (G/T) of 56 dB at all stations. This G/T will be independent of whether the transmitter is in operation and will apply when the polarization is the same as the transmitter or opposite to the transmitter. Uplink and downlink polarization will be independent, and DSS 25 and 26 will be able to provide simultaneous RCP and LCP because they have two X-band downconverters. The remaining stations will provide selectable RCP or LCP. Other receive characteristics will be as described in Tables 6 and 7.

3.1.3 Ka-Band Downlink Performance

The same technology used at X-band is expected to provide a peak vacuum Ka-band G/T of at least 63.6 dB at all stations. Selectable RCP or LCP will be available, however monopulse tracking will only be available for RCP. Other receive characteristics will be as described in Table 7.

Table 1. Capabilities of DSN BWG and HSB Antennas

Antenna	Type	S-band		X-band		Ka-band	
		Uplink*	Downlink†	Uplink*	Downlink†	Uplink*	Downlink†
DSS 24	BWG	20 kW	1	—	1	—	—
DSS 25	BWG	—	—	4 kW	1	800 W	1
DSS 25	BWG	—	—	4 kW	2	—	—
DSS 27	HSB	200 W	1	—	—	—	—
DSS 34	BWG	20 kW	1	4 kW	1	—	—
DSS 54	BWG	20 kW	1	4 kW	1	—	—

Notes:

* An entry in this column refers to the maximum available uplink power. A dash means that no capability is available.

† An entry in this column refers to the maximum number of Low Noise Amplifiers and receiver front-ends that are available for this band. A dash mean that no capability is available.

Table 2. S-Band Transmit Characteristics, DSS 24, 34, and 54

Parameter	Value	Remarks
ANTENNA		
Gain at 2115 MHz (dBi)	56.1, +0.2, –0.3 dB	At peak of gain versus elevation curve, referenced to feedhorn aperture for matched polarization; no atmosphere included; triangular probability density function (PDF) tolerance.
Transmitter Waveguide Loss (dB)	0.6 ±0.1	20-kW transmitter output terminal (waterload switch) to feedhorn aperture
Half-Power Beamwidth (deg)	0.263 ±0.020	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP or LCP	One polarization at a time, remotely selected. Polarization must be the same as received polarization.
Ellipticity (dB)	1.0 (max)	Peak-to-peak axial ratio defined as the ratio of peak-to-trough received voltages with a rotating linearly polarized source and the feed configured as a circularly (elliptically) polarized receiving antenna

Table 2. S-Band Transmit Characteristics, DSS 24, 34, and 54 (Continued)

Parameter	Value	Remarks
ANTENNA (Continued)		
Pointing Loss (dB)		
Angular	See module 302	Also see Figure 18
CONSCAN	0.01	X-band CONSCAN reference set for 0.1 dB loss
	0.1	S-band CONSCAN reference set for 0.1 dB loss
EXCITER AND TRANSMITTER		
Frequency Range Covered (MHz)	2025–2120	Power amplifier is step-tunable over the specified range in six 20-MHz segments, with 5-MHz overlap between segments. Tuning between segments can be accomplished in 30 seconds.
Instantaneous 1-dB Bandwidth (MHz)	20	
Coherent with Earth Orbiter S-Band D/L Allocation	2028.8–2108.7	240/221 turnaround ratio
Coherent with deep space S-Band D/L channels	2110.2–2117.7	240/221 turnaround ratio
Coherent with deep space X-Band D/L channels	2110.2–2119.8	880/221 turnaround ratio
RF Power Output (dBm)		Referenced to 20-kW transmitter output terminal (waterload switch). Settability is limited to 0.25 dB by measurement equipment precision.
2025–2070 MHz	53.0–73.0, +0.0, –1.0	
2070–2090 MHz	53.0–67.0, +0.0, –1.0	S-band uplink is restricted to 5 kW over 2070–2090 frequency range
2060–2120 MHz	53.0–73.0, +0.0, –1.0	

Table 2. S-Band Transmit Characteristics, DSS 24, 34, and 54 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
Power output varies across the bandwidth and may be as much as 1 dB below nominal rating. Performance will also vary from tube to tube. Normal procedure is to run the tubes saturated, but unsaturated operation is also possible. The point at which saturation is achieved depends on drive power and beam voltage. The 20-kW tubes are normally saturated for power levels greater than 60 dBm (1 kW). Minimum power out of the 20-kW tubes is about 53 dBm (200 W). Efficiency of the tubes drops off rapidly below nominal rated output.		
EIRP (dBm)	128.5, +0.2, –1.0 dB	At gain set elevation angle, referenced to feedhorn aperture
Tunability		At transmitter output frequency
Phase Continuous Tuning Range (MHz)	2.0	
Maximum Tuning Rate (kHz/s)	±12.1	
Frequency Error (Hz)	0.012	Average over 100 ms with respect to frequency specified by predicts
Ramp Rate Error (Hz/s)	0.001	Average over 4.5 s with respect to rate calculated from frequency predicts
Stability		At transmitter output frequency
Output Power Stability (dB)		Over 12-h period
Saturated Drive	0.5	
Unsaturated Drive	1.0	
Incidental AM (dB)	60	Below carrier
Group Delay Stability (ns)	≤3.3	Ranging modulation signal path (see module 203) over 12-h period
Frequency Stability		Allan deviation
1000 s	5.0×10^{-14}	
Spurious Output (dB)		Below carrier
2nd Harmonic	–85	
3rd Harmonic	–85	
4th Harmonic	–140	At input to X-band horn, with transmitter set for 20-kW output

Table 3. S-Band Transmit Characteristics, DSS 27

Parameter	Value	Remarks
ANTENNA		
Gain at 2115 MHz (dBi)	54.4, +0.2, –0.3 dB	At peak of gain versus elevation angle curve, referenced to feedhorn aperture for matched polarization; no atmosphere included; triangular PDF tolerance.
Transmitter Waveguide Loss (dB)	0.6 ±0.1	20-kW transmitter output terminal (waterload switch) to feedhorn aperture
Half-Power Beamwidth (deg)	0.263 ±0.020	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP or LCP	One polarization at a time, remotely selected. Polarization must be the same as received polarization.
Ellipticity (dB)	1.0 (max)	Peak-to-peak axial ratio defined as the ratio of peak-to-trough received voltages with a rotating linearly polarized source and the feed configured as a circularly (elliptically) polarized receiving antenna
Pointing Loss		
Angular	See module 302	Also see Figure 18
EXCITER AND TRANSMITTER		
Frequency range covered (MHz)	2025–2120	
Coherent with Earth orbiter S-Band D/L allocation	2028.8–2108.7	240/221 turnaround ratio
Coherent with deep space S-Band D/L channels	2110.2–2117.7	240/221 turnaround ratio
Coherent with deep space X-Band D/L channels	2110.2–2119.8	880/221 turnaround ratio. No X-band receiver is available at DSS 27
RF Power Output (dBm)	47.0–53.0, ±0.5 dB	Referenced to 200 W transmitter output terminal (power load switch). Settability is limited to 0.25 dB by measurement equipment precision.

Table 3. S-Band Transmit Characteristics, DSS 27 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued) Power output varies across the bandwidth and may be as much as 1 dB below nominal rating. The 200 W tube is a fixed beam klystron designed to saturate at its rated power. Operation at less than the nominal 200 W is accomplished by operating the tube unsaturated. Minimum power out of is about 47 dBm (50 W).		
EIRP (dBm)	106.8 ±0.6 dB	At gain set elevation angle, referenced to feedhorn aperture
Tunability (Hz)	100	At transmitter output frequency
Output Power Stability (dB)	±0.25	Worst case over 8-h period using 30-m sample intervals
Spurious Output (dB)		Below carrier
2025–2120 MHz	–88	
2200–2300 MHz	–94	
2nd Harmonic	–60	
3rd Harmonic	–60	
8400–8500 MHz	–94	

Table 4. X-Band Transmit Characteristics, DSS 25, 26, 34, and 54

Parameter	Value	Remarks
ANTENNA		
Gain at 7145 MHz (dBi)	67.1, +0.2, –0.3 dB	At peak of gain versus elevation angle curve, referenced to feedhorn aperture for matched polarization; no atmosphere included; triangular PDF tolerance.
Transmitter Waveguide Loss (dB)	0.4 ±0.1	4-kW transmitter output terminal (waterload switch) to feedhorn aperture
Half-Power Beamwidth (deg)	0.0777 ±0.0040	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP or LCP	One polarization at a time, remotely selected, independent of received polarization.

Table 4. X-Band Transmit Characteristics, DSS 25, 26, 34, and 54 (Continued)

Parameter	Value	Remarks
ANTENNA (Continued)		
Ellipticity (dB)	1.0 (max)	Peak-to-peak axial. See Table 2 for definition.
Pointing Loss (dB)		
Angular	See module 302	Also see Figure 19
CONSCAN	0.1	X-band CONSCAN reference set for 0.1 dB loss
EXCITER AND TRANSMITTER		
Frequency range covered (MHz)	7145–7190	
Coherent with deep space S-Band D/L channels	7147.3–7177.3	240/749 turnaround ratio
Coherent with deep space X-Band D/L channels	7149.6–7188.9	880/749 turnaround ratio
RF Power Output (dBm)	47.0–66.0, ±0.5 dB	Referenced to 4-kW transmitter output terminal (waterload switch). Settability is limited to 0.25 dB by measurement equipment precision.
Power output varies across the bandwidth and may be as much as 1 dB below nominal rating. The 4 kW tubes are fixed beam klystrons designed to saturate at their rated power however performance varies from tube to tube. Operation at less than the nominal 4.0 kW is unsaturated. Minimum power output is about 47 dBm (50 W). Efficiency of the tubes drops off rapidly below nominal rated output.		
EIRP (dBm)	133.1 ±0.7 dB	At gain set elevation angle, referenced to feedhorn aperture
Tunability		At transmitter output frequency
Phase Continuous Tuning Range (MHz)	2.0 MHz	
Maximum Tuning Rate (kHz/s)	±12.1	

Table 4. X-Band Transmit Characteristics, DSS 25, 26, 34, and 54 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
Tunability (Continued)		
Frequency Error (Hz)	0.012	Average over 100 ms with respect to frequency specified by predicts
Ramp Rate Error (Hz/s)	0.001	Average over 4.5 s with respect to rate calculated from frequency predicts
Stability		At transmitter output frequency
Output Power Stability (dB)	0.2	First Differences, 10–1000 s intervals over 12-h period
Output Power Variation (dB)		Across frequency band over 12-h period
Saturated Drive	0.25	
Unsaturated Drive	1.0	
Group Delay Stability (ns)	≤1.0	Ranging modulation signal path over 12-h period (see module 203)
Frequency Stability		Allan deviation
1 s	3.3×10^{-13}	
10 s	5.0×10^{-14}	
1000–3600 s	2.7×10^{-15}	
Spurious Output (dB)		Below carrier
1–10 Hz	–50	
10 Hz–1.5 MHz	–60	
1.5 MHz–8 MHz	–45	
2nd Harmonic	–75	
3rd, 4th & 5th Harmonics	–60	

Table 5. Ka-Band Transmit Characteristics, DSS 25

Parameter	Value	Remarks
ANTENNA		
Gain at 34200 MHz (dBi)	79.5, +0.2, –0.3 dB	At peak of gain versus elevation angle curve, referenced to feedhorn aperture for matched polarization; no atmosphere included; triangular PDF tolerance.
Transmitter Waveguide Loss (dB)	0.25 ±0.1	800W transmitter output terminal (waterload switch) to feedhorn aperture
Half-Power Beamwidth (deg)	0.0162 ±0.0010	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP	
Ellipticity (dB)	1.0 (max)	Peak-to-peak axial. See Table 2 for definition.
Pointing Loss		CONSCAN is not available.
Angular	See module 302	Also see Figure 20
EXCITER AND TRANSMITTER		
Frequency range covered (MHz)	34200–34700	
Coherent with deep space Ka-Band D/L channels	34343.2–34570.9	3344/3599 turnaround ratio
Coherent with deep space X-Band D/L channels	34354.3–34554.2	880/3599 turnaround ratio
RF Power Output (dBm)	47.0–59.0, ±0.5 dB	Referenced to 800 W transmitter output terminal (waterload switch). Settability is limited to 0.25 dB by measurement equipment precision.
Power output varies across the bandwidth and may be as much as 1 dB below nominal rating. The 800 W tube is a fixed beam klystron designed to saturate at its rated power. Operation at less than the nominal 800 W is unsaturated. Minimum power output is about 47 dBm (50 W).		
EIRP (dBm)	138.2, +0.6, –0.5 dB	At gain set elevation angle, referenced to feedhorn aperture
Stability		At transmitter output frequency
Output Power Variation (dB)		Across frequency band over 12 h

Table 5. Ka-Band Transmit Characteristics, DSS 25 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
Coherent with deep space X-Band D/L channels	34354.3–34554.2	880/3599 turnaround ratio
RF Power Output (dBm)	47.0–59.0, ±0.5 dB	Referenced to 800 W transmitter output terminal (waterload switch). Settability is limited to 0.25 dB by measurement equipment precision.
Power output varies across the bandwidth and may be as much as 1 dB below nominal rating. The 800 W tube is a fixed beam klystron designed to saturate at its rated power. Operation at less than the nominal 800 W is unsaturated. Minimum power output is about 47 dBm (50 W).		
EIRP (dBm)	138.2, +0.6, –0.5 dB	Referenced to feed
Stability		At transmitter output frequency
Output Power Variation (dB)		Across frequency band over 12 h
Saturated Drive	0.25	
Unsaturated Drive	≤1.0	
Frequency Stability		Allan deviation
1 s	3.3×10^{-13}	
10 s	5.2×10^{-14}	
1000–3600 s	3.1×10^{-15}	
1000–3600 s	3.1×10^{-15}	
Spurious Output (dB)		Below carrier
1–10 Hz	–50	
10 Hz–1.5 MHz	–60	
1.5 MHz–8 MHz	–45	

Table 6. S- and X-Band Receive Characteristics, DSS 24, 34, and 54

Parameter	Value	Remarks
ANTENNA		
Gain (dBi)		At peak of gain versus elevation angle curve, referenced to feedhorn aperture (feed and feedline losses are accounted for in system temperature), for matched polarization; no atmosphere included; triangular PDF tolerance. See Figures 6, 8, and 9 for representative gain versus elevation curves.
S-Band (2295 MHz)	56.8, +0.1, –0.2 dB	
X-Band (8420 MHz)	68.2, +0.1, –0.2 dB	
Half-Power Beamwidth (deg.)		Angular width (2-sided) between half-power points at specified frequency
S-Band	0.242 ±0.020	
X-Band	0.0660 ±0.0040	
Polarization		Remotely selected
S-Band	RCP or LCP	Same as transmit polarization
X-Band	RCP or LCP	Same as or opposite from transmit polarization
Ellipticity (dB)		Peak-to-peak voltage axial ratio, RCP and LCP. See definition in Table 2.
S-Band	≤1.0	
X-Band	≤0.7	
Pointing Loss (dB, 3 sigma)		
Angular	See module 302	Also see Figures 18 and 19
CONSCAN		
S-Band	0.03	Loss at S-band when using X-band CONSCAN reference set for 0.1 dB loss at X-band
	0.1	Recommended value when using S-band CONSCAN reference
X-Band	0.1	Recommended value when using X-band CONSCAN reference

Table 6. S- and X-Band Receive Characteristics, DSS 24, 34, and 54 (Continued)

Parameter	Value	Remarks
RECEIVER		
Frequency Ranges Covered (MHz))		
S-Band	2200–2300	
X-Band	8400–8500	
Recommended Maximum Signal Power (dBm)	-90.0	At LNA input terminal
Recommended Minimum Signal Power (dBm)	See Table 12	
System Noise Temperature (K)		Near zenith, no atmosphere included. See Figures 12, 14, and 15 for representative system temperature versus elevation curves. Tolerances have a triangular PDF.
S-Band (2200–2300 MHz) Non-Diplexed Path		Referenced to feedhorn aperture.
DSS 24	28.3, –1.0, +2.0 K	
DSS 34	30.7, –1.0, +2.0 K	
DSS 54	28.9, –1.0, +2.0 K	
S-Band (2200–2300 MHz) Diplexed Path		Referenced to feedhorn aperture.
DSS 24	34.8, –1.0, +2.0 K	
DSS 34	39.3, –1.0, +2.0 K	
DSS 54	37.5, –1.0, +2.0 K	
X-Band (8400–8500 MHz) Non-Diplexed Path		X-band only operation (S/X-band dichroic plate retracted). Referenced to feedhorn aperture.
DSS 24	23.2, –1.0, +2.0 K	LNA = MASER
DSS 34	28.0, –1.0, +2.0 K	LNA = HEMT
DSS 54	21.1, –1.0, +2.0 K	LNA = MASER

Table 6. S- and X-Band Receive Characteristics, DSS 24, 34, and 54 (Continued)

Parameter	Value	Remarks
RECEIVER (Continued)		
System Noise Temperature (K), (Continued)		
X-Band (8400–8500 MHz) Diplexed Path		X-band only operation (dichroic plate retracted). Referenced to feedhorn aperture.
DSS 34	35.5, –1.0, +2.0 K	LNA = HEMT
DSS 54	28.6, –1.0, +2.0 K	LNA = MASER
X-Band (8400–8500 MHz) Non-Diplexed Path		S/X-band operation. Referenced to feedhorn aperture.
DSS 24	24.6, –1.0, +2.0 K	LNA = MASER
DSS 34	29.7, –1.0, +2.0 K	LNA = HEMT
DSS 54	22.8, –1.0, +2.0 K	LNA = MASER
X-Band (8400–8500 MHz) Diplexed Path		S/X-band operation. Referenced to feedhorn aperture.
DSS 34	37.2, –1.0, +2.0 K	LNA = HEMT
DSS 54	30.2, –1.0, +2.0 K	LNA = MASER
Carrier Tracking Loop Noise B/W (Hz)	0.25–200	Effective one-sided, noise-equivalent carrier loop bandwidth (B_L)

Table 7. X- and Ka-Band Receive Characteristics, DSS 25 and 26

Parameter	Value	Remarks
ANTENNA		
Gain (dBi)		At peak of gain versus elevation angle curve, referenced to feedhorn aperture (feed and feedline losses are accounted for in system temperature), for matched polarization; no atmosphere included; triangular PDF tolerance. See Figures 10 and 11 for representative DSS 25 gain versus elevation curves.
X-Band (8420 MHz)	68.4, +0.1, –0.2 dB 68.3, +0.1, –0.2 dB	DSS 25 DSS 26
Ka-Band (32000 MHz)		DSS 25 only
	79.0, +0.3, –0.3 dB	Ka-band only operation (X-Ka dichroic plate retracted).
	78.8, +0.2, –0.3 dB	X/Ka-band operation
Half-Power Beamwidth (deg.)		Angular width (2-sided) between half-power points at specified frequency
X-Band	0.0660 ±0.0040	
Ka-Band	0.0174 ±0.0020	DSS 25 only
Polarization		
X-Band DSS 25	RCP and LCP	Both polarizations simultaneously available; polarization using diplexed path is remotely selected
X-Band DSS 26	RCP or LCP	One polarization at a time
Ka-Band	RCP	DSS 25 only
Ellipticity (dB)		Peak-to-peak voltage axial ratio. See definition in Table 2.
X-Band	≤0.7	RCP and LCP
Ka-Band	≤1.0	
Pointing Loss (dB, 3 sigma)		
Angular	See module 302	Also see Figures 19 and 20
CONSCAN		(Not available at Ka-band)

Table 7. X- and Ka-Band Receive Characteristics, DSS 25 and 26 (Continued)

Parameter	Value	Remarks
ANTENNA (Continued)		
Pointing Loss (dB, 3 sigma) (Continued)		
X-Band	0.1	Recommended value when using X-band CONSCAN reference
Monopulse		DSS 25 only. Receiver loop SNR ≥35 dB
X-Band	0.007	Using Ka-band monopulse reference
Ka-Band	0.1	
RECEIVER		
Frequency Ranges (MHz)		
X-Band	8400–8500	
Ka-Band	31800–32300	
Recommended Maximum Signal Power (dBm)	-90.0	At LNA input terminal
Recommended Minimum Signal Power (dBm)	See Table 12	
System Noise Temperature (K)		Near zenith, no atmosphere included. See Figures 16 and 17 for DSS 25 system temperature versus elevation curves. Tolerances have a triangular PDF.
X-Band (8400–8500 MHz) Non-Diplexed Path		Referenced to feedhorn aperture.
DSS 25, LNA 1	22.1, –1.0, +2.0 K	LNA = MASER
DSS 25, LNA 2	35.9, –1.0, +2.0 K	LNA = HEMT
DSS 26	N/A	
X-Band (8400–8500 MHz) Diplexed Path		Referenced to feedhorn aperture.
DSS 25, LNA 1	29.6, –1.0, +2.0 K	LNA = MASER
DSS 25, LNA 2	43.4, –1.0, +2.0 K	LNA = HEMT
DSS 26, LNA 1 (RCP)	25.8 –1.0, +2.0 K	LNA = HEMT
DSS 26, LNA 2 (LCP)	26.5 –1.0, +2.0 K	LNA = HEMT

Table 7. X- and Ka-Band Receive Characteristics, DSS 25 and 26 (Continued)

Parameter	Value	Remarks
RECEIVER (Continued)		
System Noise Temperature (K) (Continued)		
DSS 26, LNA 1 & 2	26.2 –1.0, +2.0 K	LNA = HEMT
Ka-Band (31800–32300 MHz)		Ka-band only operation (X/Ka-band dichroic plate retracted), referenced to feedhorn aperture.
DSS 25	29.3, –1.0, +2.0	LNA = HEMT
DSS 26	N/A	
Ka-Band (31800–32300 MHz)		X/Ka-band operation, referenced to feedhorn aperture.
DSS 25	32.8, –1.0, +2.0	LNA = HEMT
DSS 26	N/A	
Carrier Tracking Loop Noise B/W (Hz)	0.25–200	Effective one-sided, noise-equivalent carrier loop bandwidth (B_L)

Table 8. S-Band Receive Characteristics, DSS 27

Parameter	Value	Remarks
ANTENNA		
Gain (dBi)		At peak of gain versus elevation angle curve, referenced to feedhorn aperture (feed and feedline losses are accounted for in system temperature), for matched polarization; no atmosphere included; triangular PDF tolerance. See Figures for elevation dependency.
S-Band	55.1, +0.1, –0.2 dB	
Half-Power Beamwidth (deg)		Angular width (2-sided) between half-power points at specified frequency
S-Band	0.242 ±0.020	
Polarization		Remotely selected
S-Band	RCP or LCP	Same as transmit polarization

Table 8. S-Band Receive Characteristics, DSS 27 (continued)

Parameter	Value	Remarks
ANTENNA (Continued)		
Ellipticity (dB)		Peak-to-peak voltage axial ratio, RCP and LCP. See definition in Table 2.
S-Band	≤1.0	
Pointing Loss (dB, 3-sigma)		
Angular	See module 302	Also see Figure 18
RECEIVER		
Frequency Ranges Covered (MHz))		
S-Band	2200–2300	
Recommended Maximum Signal Power (dBm)	–90.0	At LNA input terminal
Recommended Minimum Signal Power (dBm)	See Table 12	
S-Band System Noise Temperature (K) (2200–2300 MHz)		With respect to feedhorn aperture, near zenith, no atmosphere included. See Figure 13 for elevation dependency. Tolerances have a triangular PDF.
DSS 27	101, –1.0, +2.0 K	LNA = Room temperature HEMT
Incremental Tunability (kHz)	10	Continuously variable tuning around center frequency available in ±15 kHz and ±300 kHz ranges
Carrier Tracking Loop Noise B/W (Hz)	1.0–200	Effective one-sided, noise-equivalent carrier loop bandwidth (B_L) when using Block V Receiver
Noise Bandwidth (Hz)	10 ±10%	Effective one-sided threshold noise bandwidth (B_{LO}) when using Multifunction Receiver
	30 ±10%	
	100 ±10%	
	300 ±10%	
	1000 ±10%	
	3000 ±10%	

Table 9. Gain Reduction Due to Wind Loading, 34-m BWG Antennas

Wind Speed		X-Band Gain Reduction (dB)*
(km/hr)	(mph)	
16	10	0.2
48	30	0.3
72	45	0.4

* Assumes antenna is maintained on-point using CONSCAN or an equivalent. S-band gain reduction is negligible for wind speeds up to 72 km/h (45 mph). Worst case with antenna in most adverse orientation for wind.

Table 10. System Noise Temperature Contributions due to 25% Weather

Location	Noise Temperature Contribution (K)*		
	S-band	X-band	Ka-band
Goldstone (DSS 24, 25, 26 & 27)	1.929	2.292	9.116
Canberra (DSS 34)	2.109	2.654	11.331
Madrid (DSS 54)	2.031	2.545	10.797

* From Table 1 in module 105.

Table 11. Pointing Accuracy and Pointing Loss in Various Wind Conditions

Wind Speed < 4.5 km/s (<10 mph)				
Cumulative Distribution (CD)	Pointing Error, mdeg	Pointing Loss, dB		
		S-band	X-band	Ka-band
Mean (54.4%)	1.670	0.001	0.008	0.111
90%	2.825	0.002	0.022	0.319
95%	3.251	0.002	0.029	0.422
99%	3.997	0.003	0.044	0.639
Wind Speed < 8.9 km/s (<20 mph)				
Cumulative Distribution (CD)	Pointing Error, mdeg	Pointing Loss, dB		
		S-band	X-band	Ka-band
Mean (54.4%)	3.330	0.002	0.031	0.443
90%	5.633	0.007	0.088	1.268
95%	6.483	0.009	0.116	1.679
99%	7.971	0.013	0.176	2.539
Wind Speed < 13.4 km/s (<30 mph)				
Cumulative Distribution (CD)	Pointing Error, mdeg	Pointing Loss, dB		
		S-band	X-band	Ka-band
Mean (54.4%)	5.000	0.005	0.069	0.999
90%	8.458	0.015	0.198	2.858
95%	9.734	0.019	0.262	3.786
99%	11.968	0.029	0.396	5.724

Table 12. Recommended Minimum Operating Carrier Signal Levels (dBm) for BWG Antennas Using the Block V Receiver (BVR)*

Band, LNA, and Configuration	Receiver Effective Noise Bandwidth (B_L) (Hz) †				
	0.25	1.0	2.0	20.0	200
S-Band					
DSS 24 Non-Diplexed	–179.8	–173.8	–170.8	–160.8	–150.8
DSS 34 Non-Diplexed	–179.5	–173.4	–170.4	–160.4	–150.4
DSS 54 Non-Diplexed	–179.7	–173.7	–170.7	–160.7	–150.7
DSS 24 S-Diplexed	–179.0	–173.0	–169.9	–159.9	–149.9
DSS 34 S-Diplexed	–178.5	–172.4	–169.4	–159.4	–149.4
DSS 54 S-Diplexed	–178.7	–172.6	–169.6	–159.6	–149.6
DSS 27 Diplexed		–168.5	–165.5	–155.5	–145.5
X-Band Only					
DSS 24 Non-Diplexed	–180.6	–174.5	–171.5	–161.5	–151.5
DSS 34 Non-Diplexed	–179.8	–173.7	–170.7	–160.7	–150.7
DSS 54 Non-Diplexed	–180.9	–174.9	–171.8	–161.8	–151.8
DSS 34 X-Diplexed	–178.8	–172.8	–169.8	–159.8	–149.8
DSS 54 X-Diplexed	–179.7	–173.7	–170.7	–160.7	–150.7
S/X-band					
DSS 24 Non-Diplexed	–180.3	–174.3	–171.3	–161.3	–151.3
DSS 34 Non-Diplexed	–179.5	–173.5	–170.5	–160.5	–150.5
DSS 54 Non-Diplexed	–180.6	–174.6	–171.5	–161.5	–151.5
DSS 34 Diplexed	–178.6	–172.6	–169.6	–159.6	–149.6
DSS 54 Diplexed	–179.5	–173.4	–170.4	–160.4	–150.4
X-Band LNA-1					
DSS 25 Non-Diplexed	–180.8	–174.7	–171.7	–161.7	–151.7
DSS 25 Diplexed	–179.6	–173.6	–170.6	–160.6	–150.6
DSS 26 Diplexed	–180.1	–174.0	–171.0	–161.0	–151.0

* Levels are referenced to LNA input terminals with nominal zenith system noise temperature and average clear weather (CD=0.25).

† Bandwidth is centered about the received carrier.

Table 13. Recommended Minimum Operating Carrier Signal Levels (dBm)
for BWG Antennas Using the Block V Receiver (BVR)*

Band, LNA, and Configuration	Receiver Effective Noise Bandwidth (B_L) (Hz) †				
	0.25	1.0	2.0	20.0	200
X-Band LNA-2					
DSS 25 Non-Diplexed	–178.8	–172.8	–169.8	–159.8	–149.8
DSS 25 Diplexed	–178.0	–172.0	–169.0	–159.0	–149.0
DSS 26 Diplexed	–180.1	–174.0	–171.0	–161.0	–151.0
Ka-Band Only					
DSS 25	–178.8	–172.8	–169.7	–159.7	–149.7
X/Ka-Band					
DSS 25	–178.4	–172.4	–169.4	–159.4	–149.4

* Levels are referenced to LNA input terminals with nominal zenith system noise temperature and average clear weather (CD=0.25).

† Bandwidth is centered about the received carrier.

Table 14. Recommended Minimum Operating Carrier Signal Levels (dBm)
for DSS 27 HSB Antenna Using the Multifunction Receiver (MFR)*

Band, LNA, and Configuration	Receiver Effective Noise Bandwidth (B_L) (Hz) †					
	10	30	100	300	1000	3000
S-Band						
DSS 27 Diplexed	–155.5	–150.7	–145.5	–140.7	–135.5	–130.7

* Levels are referenced to LNA input terminals with nominal zenith system noise temperature and average clear weather (CD=0.25).

† Indicated bandwidths are one-sided. That is, a value such as “30 Hz” means 30 Hz on each side of the carrier frequency for a total bandwidth of 60 Hz, and so forth

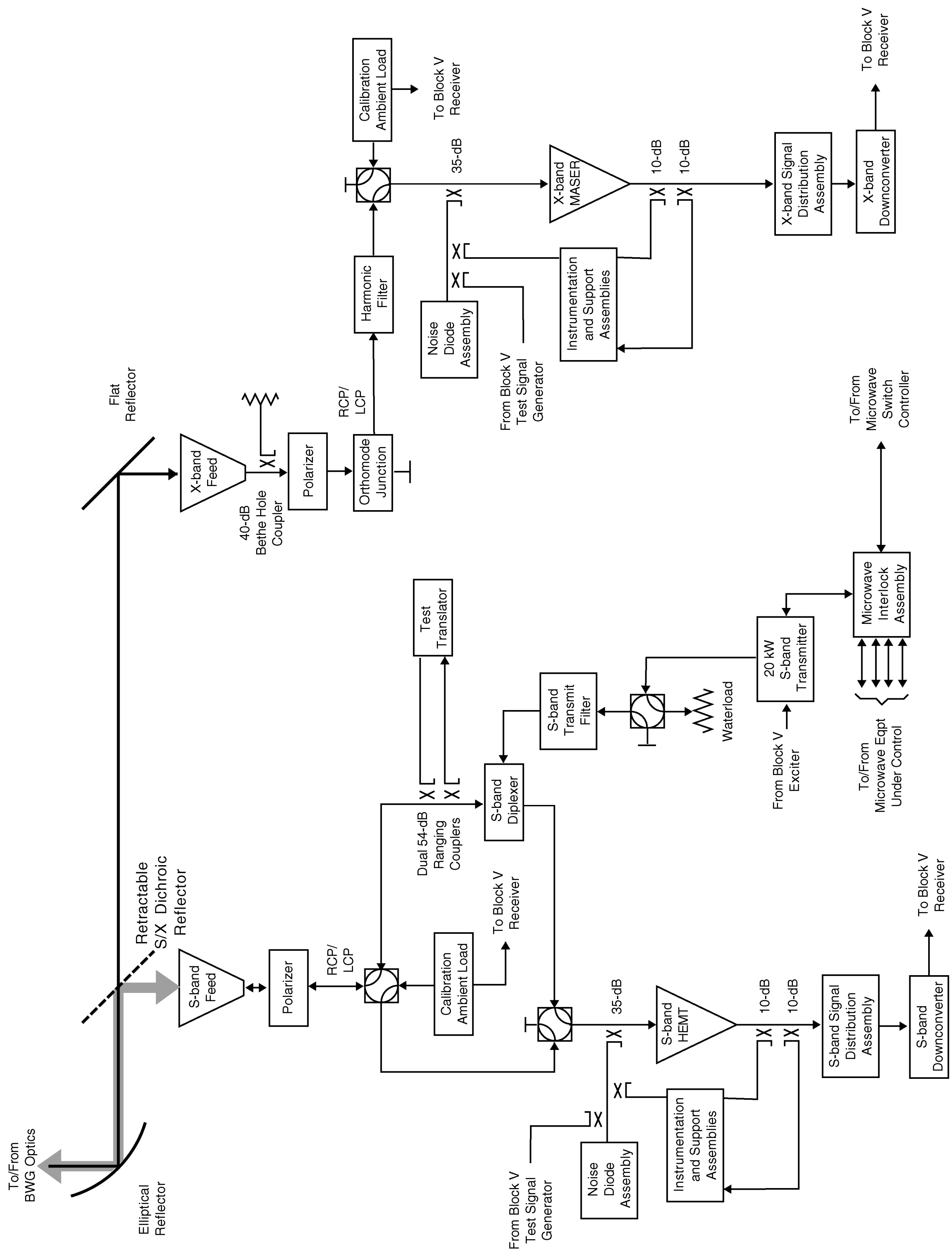


Figure 1. Functional Block Diagram of DSS 24 Antenna

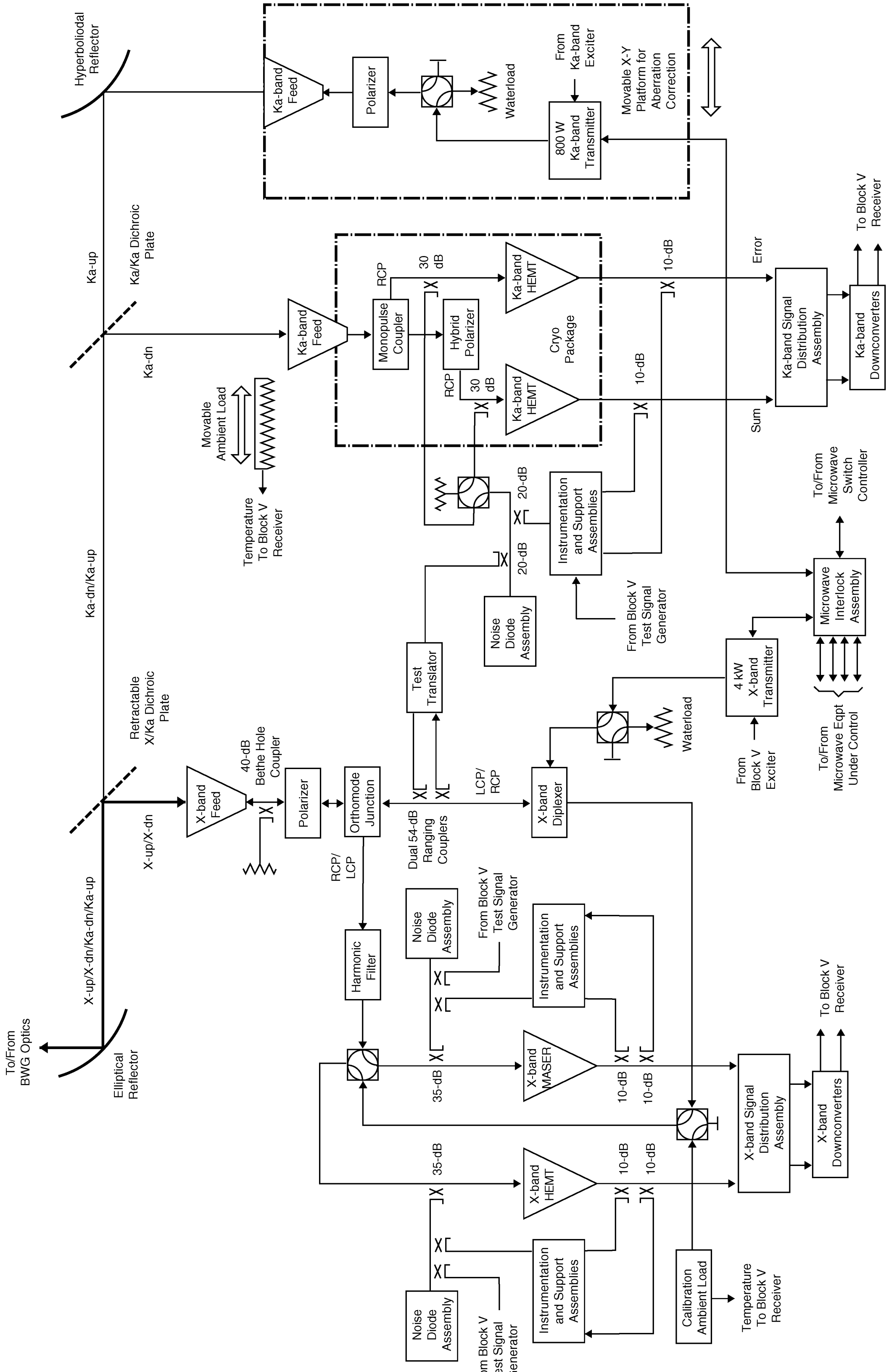


Figure 2. Functional Block Diagram of DSS 25 Antenna

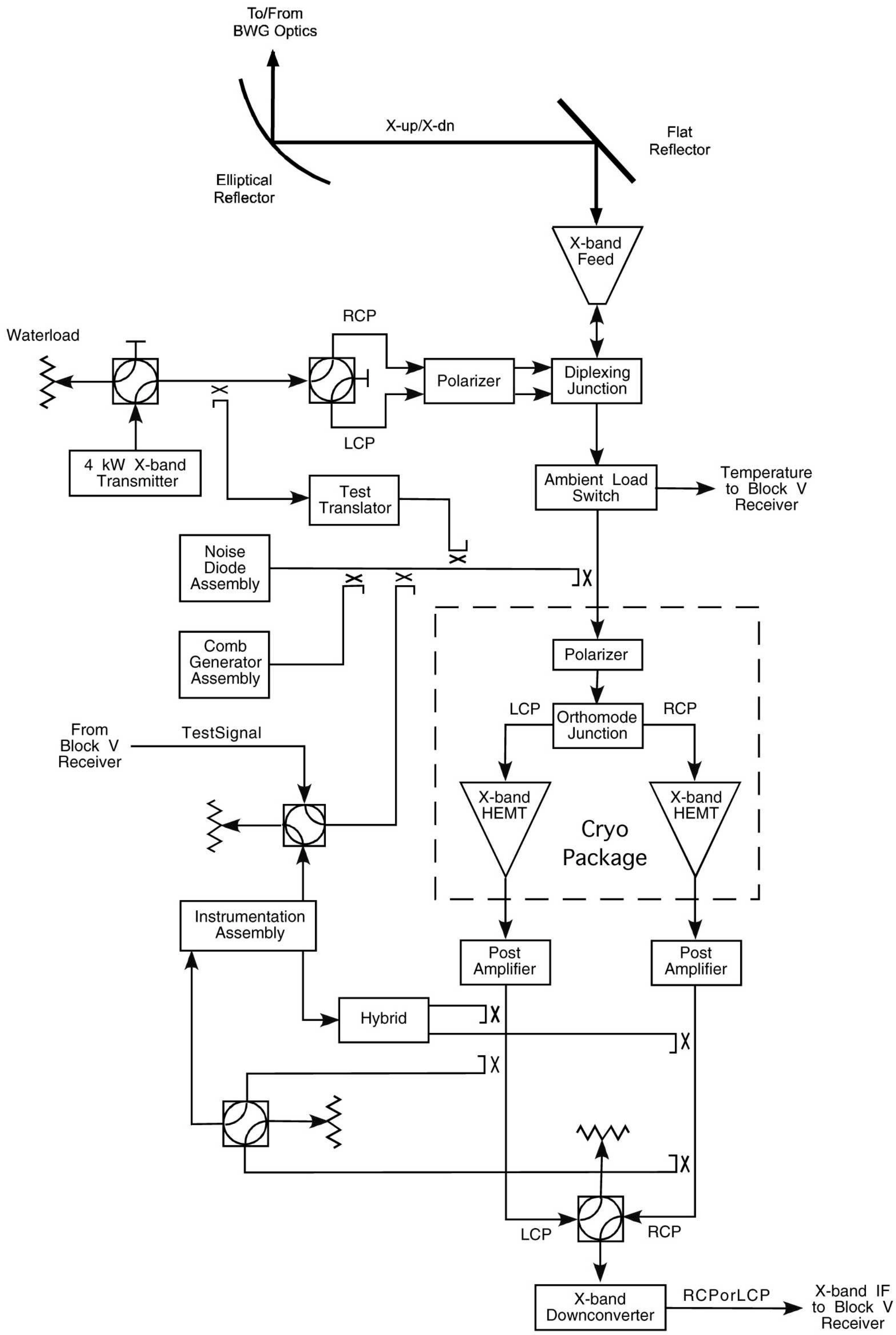
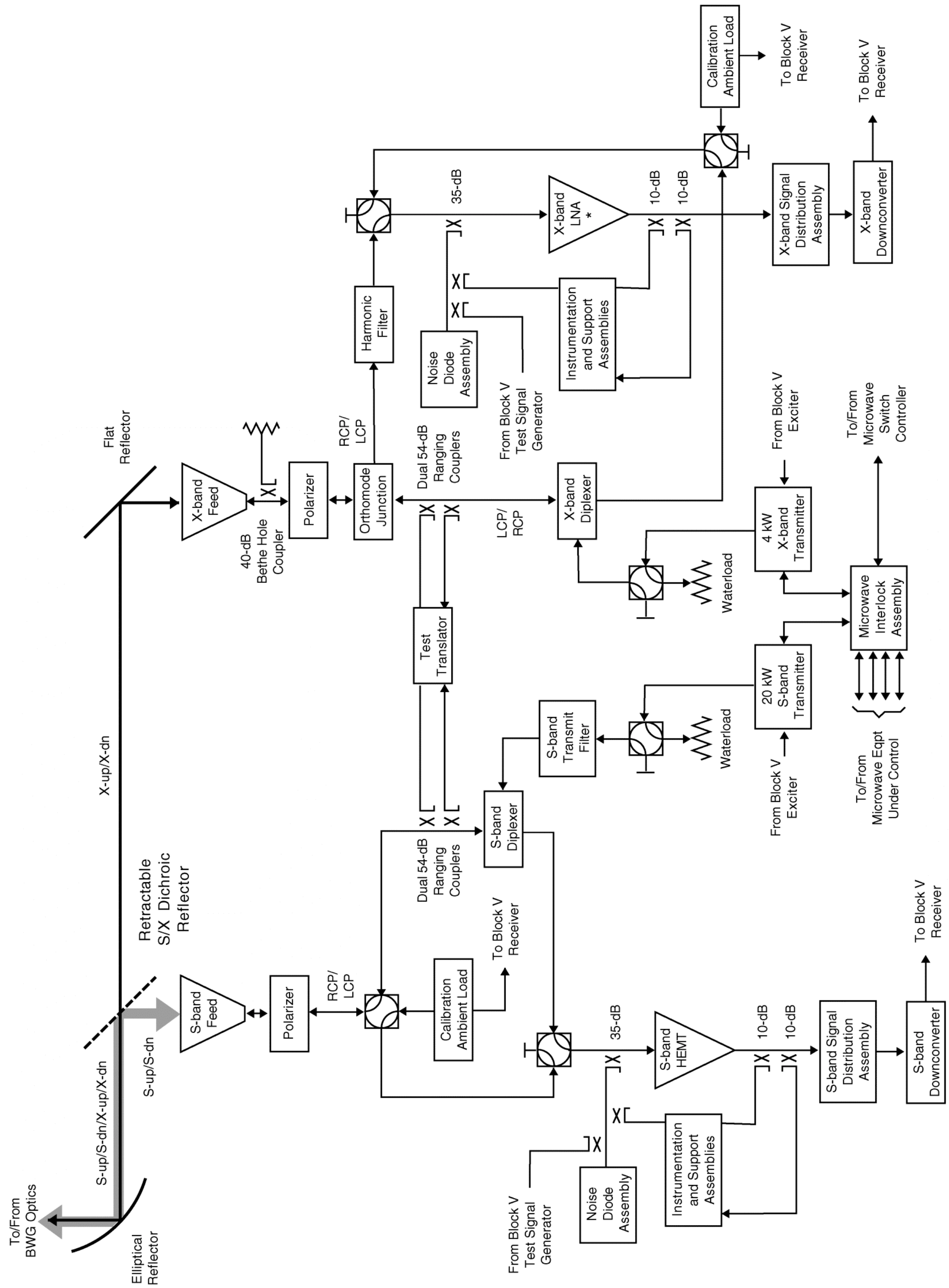


Figure 3. Functional Block Diagram of DSS 26 Antenna



NOTE: * X-band LNA is HEMT at DSS 34 and MASER at DSS 54.

Figure 4. Functional Block Diagram of DSS 34 and DSS 54 Antennas

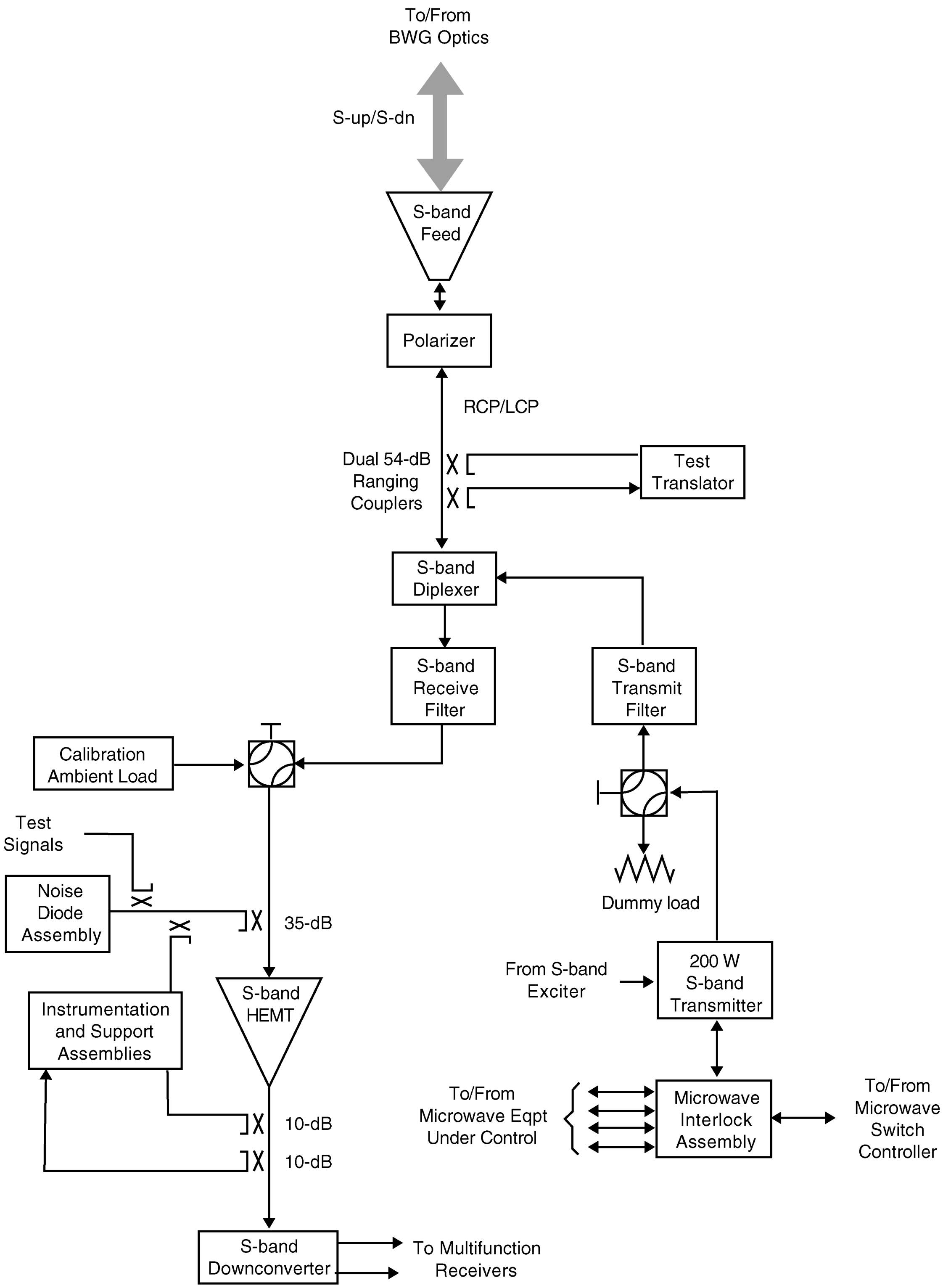


Figure 5. Functional Block Diagram of DSS 27 Antenna

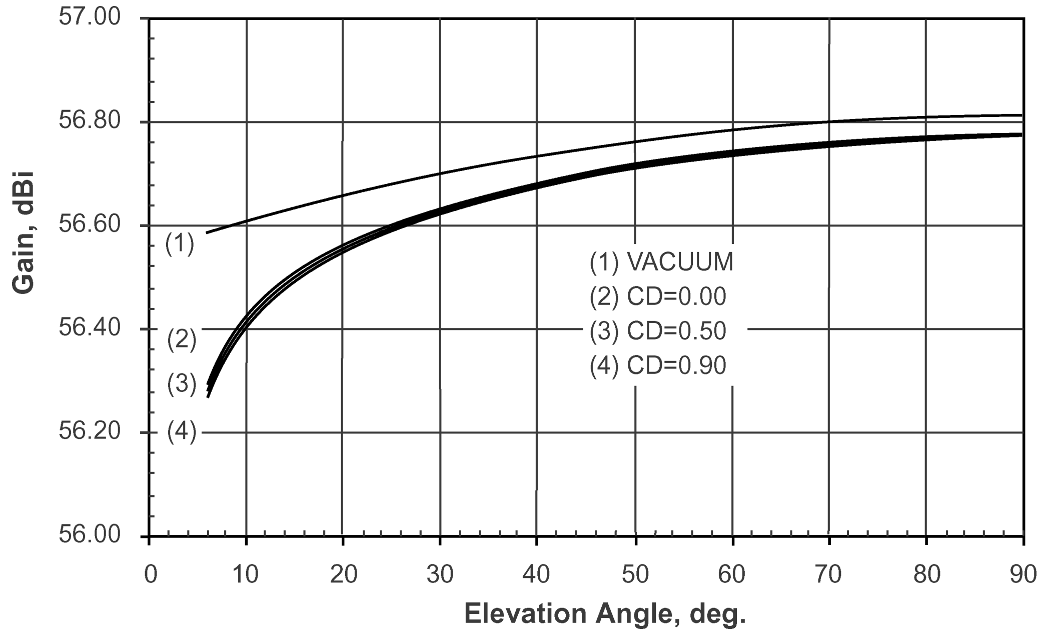


Figure 6. DSS 24 (Goldstone) S-Band Receive Gain Versus Elevation Angle, S/X Mode, 2295 MHz

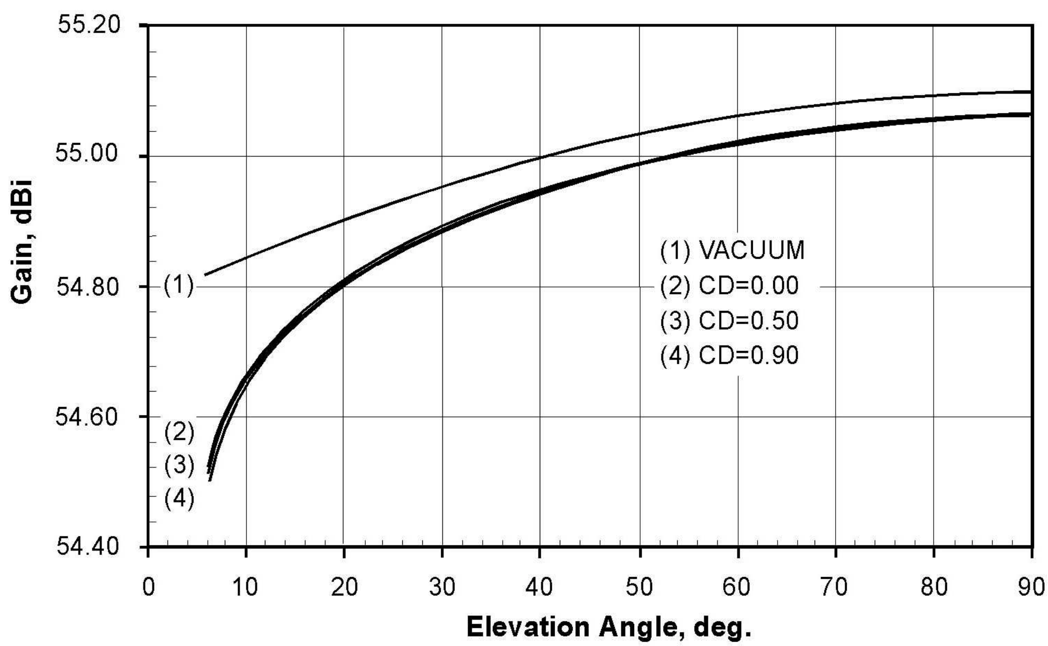


Figure 7. DSS 27 (Goldstone) S-Band Receive Gain Versus Elevation Angle, 2295 MHz

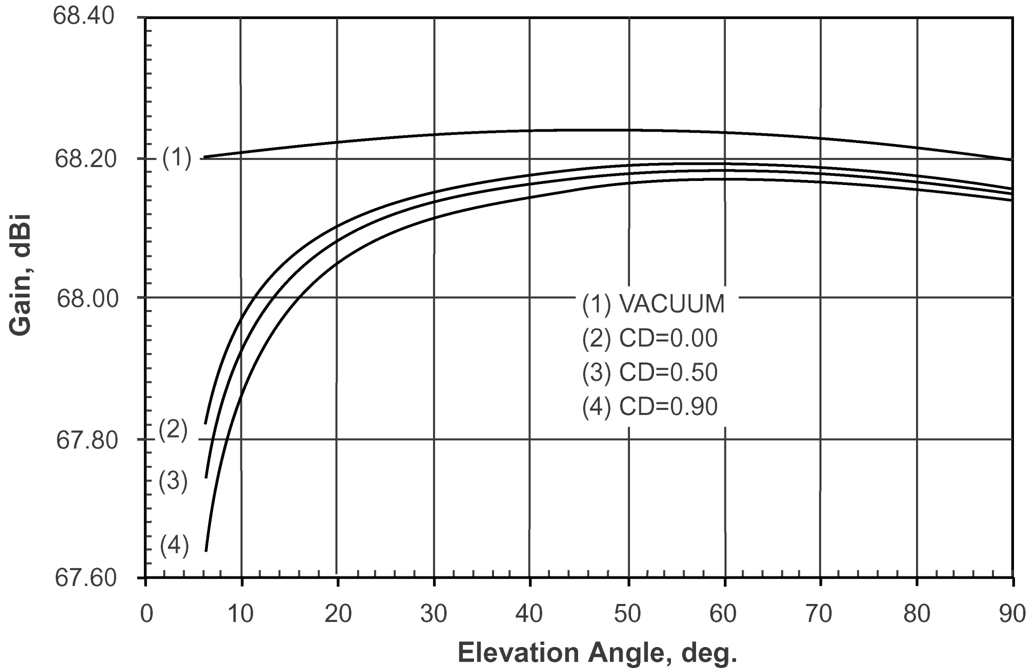


Figure 8. DSS 34 (Canberra) X-Band Receive Gain Versus Elevation Angle, S/X Mode, 8420 MHz

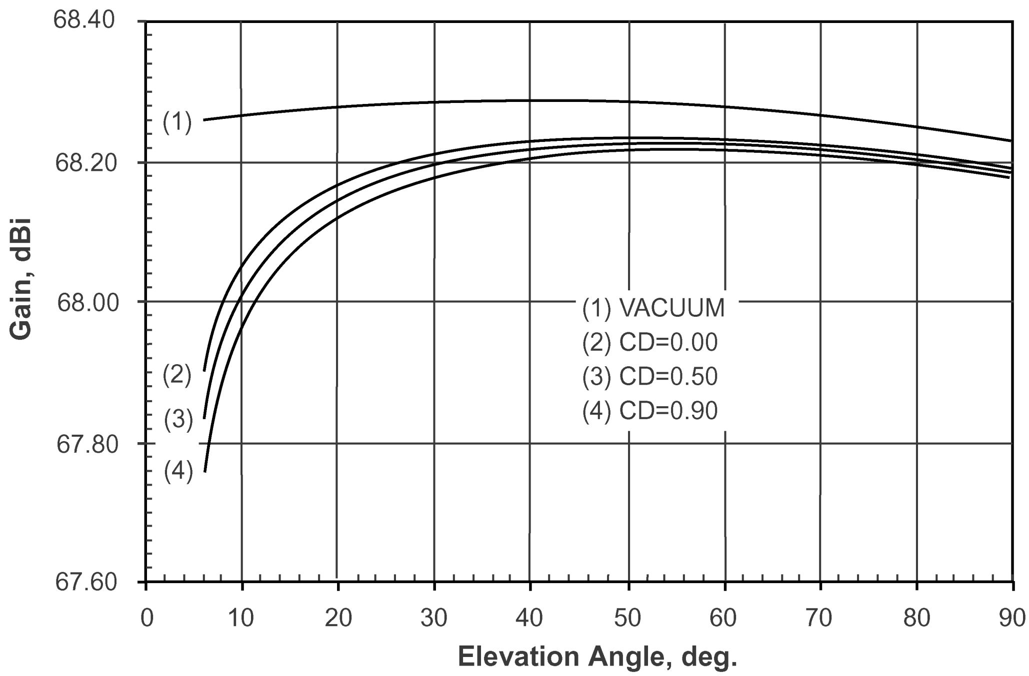


Figure 9. DSS 54 (Madrid) X-Band Receive Gain Versus Elevation Angle, X-Only Mode (S/X Dichroic Retracted), 8420 MHz

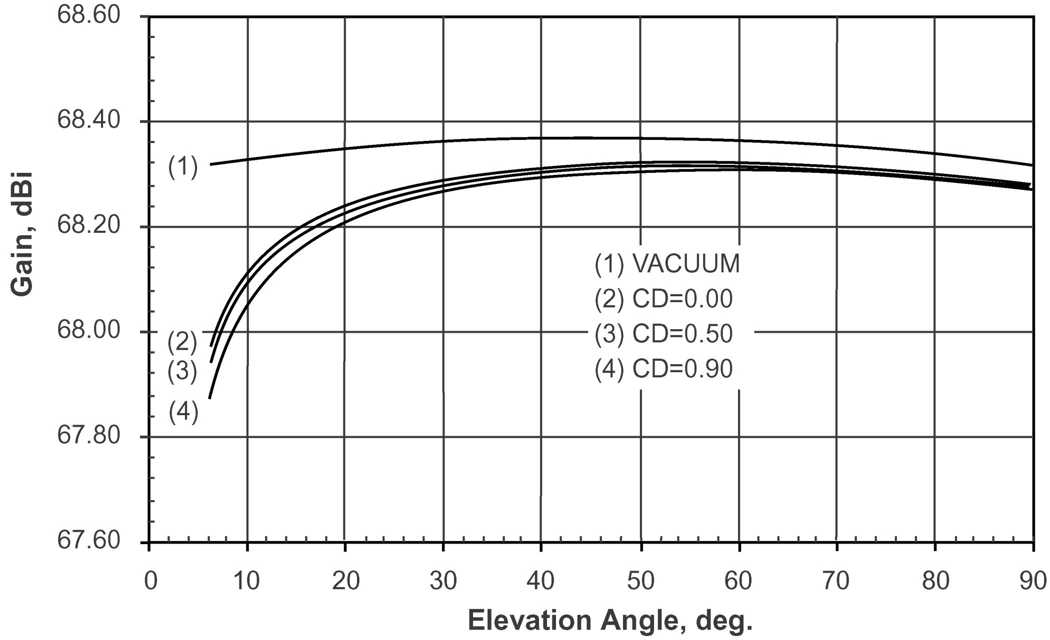


Figure 10.DSS 25 (Goldstone) X-Band Receive Gain Versus Elevation Angle, 8420 MHz

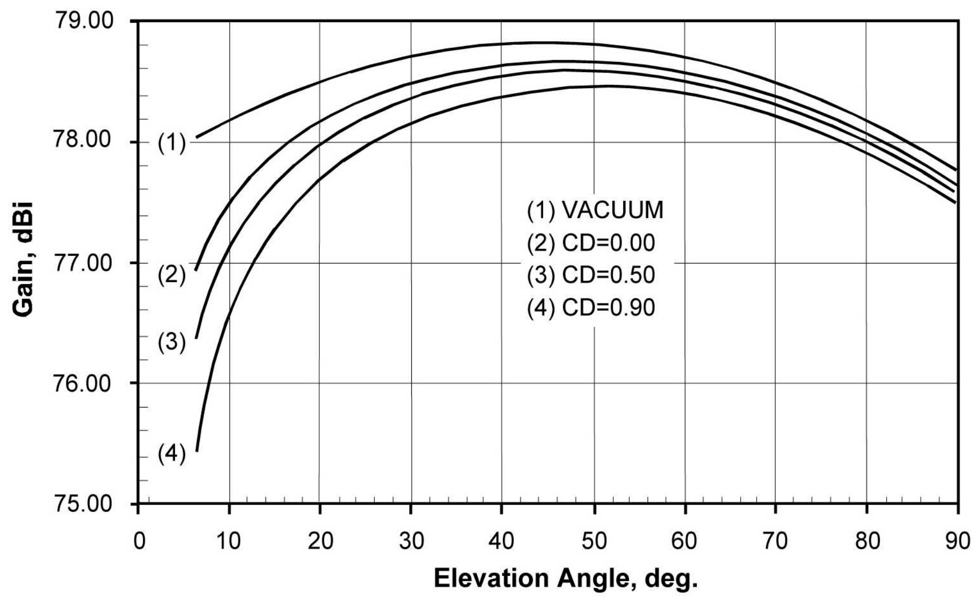


Figure 11. DSS 25 (Goldstone) Ka-Band Receive Gain Versus Elevation Angle, X/Ka Mode (X/Ka Dichroic In-Place), 32000 MHz

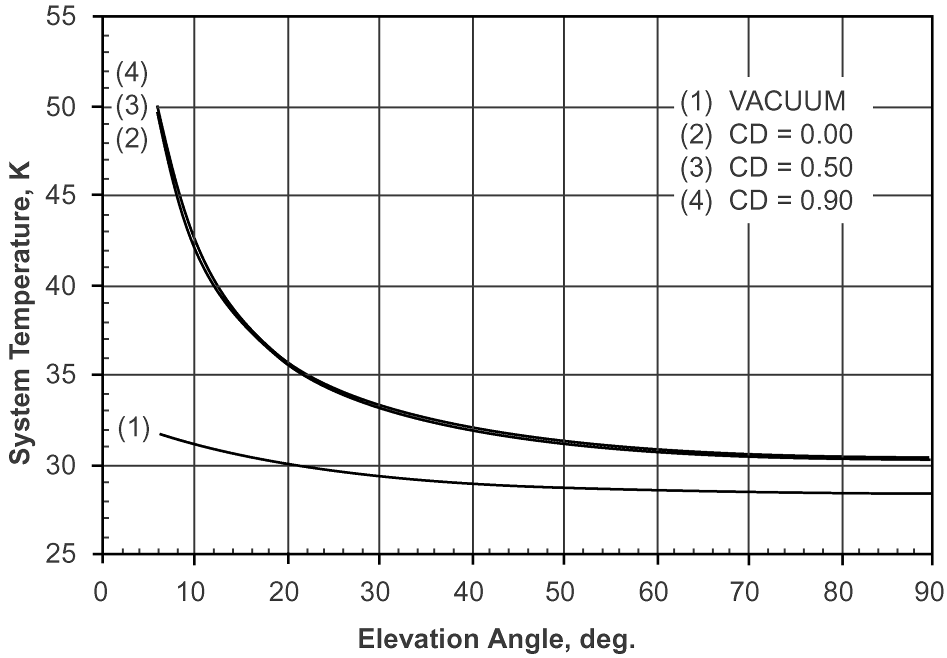


Figure 12. DSS 24 (Goldstone) S-Band System Temperature Versus Elevation Angle, S/X Mode, Non-Diplexed Path, 2295 MHz

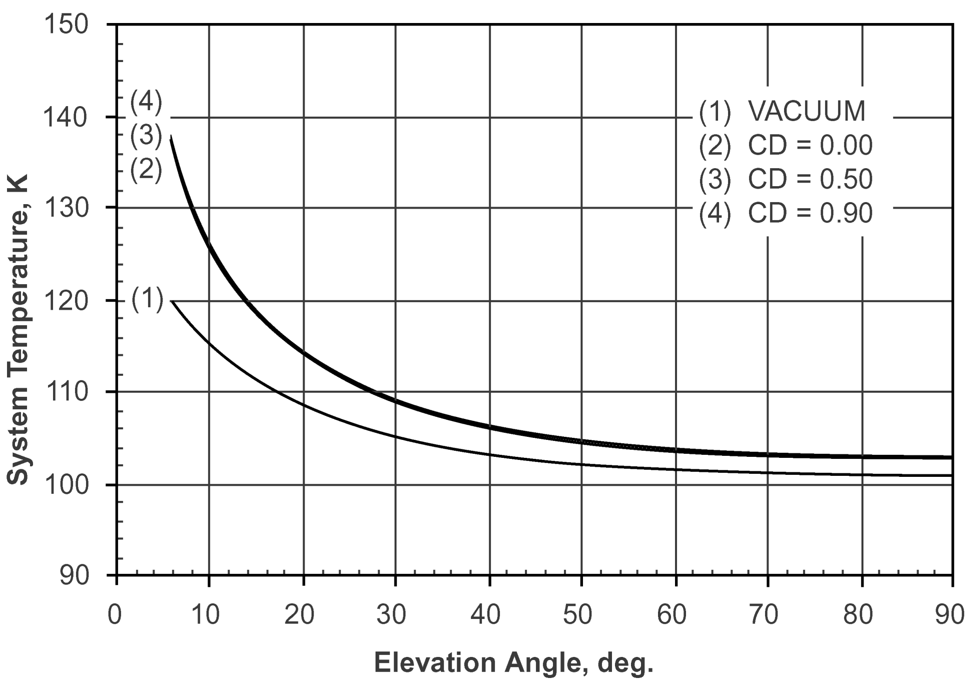


Figure 13. DSS 27 (Goldstone) S-Band System Temperature Versus Elevation Angle, Diplexed Path, 2295 MHz

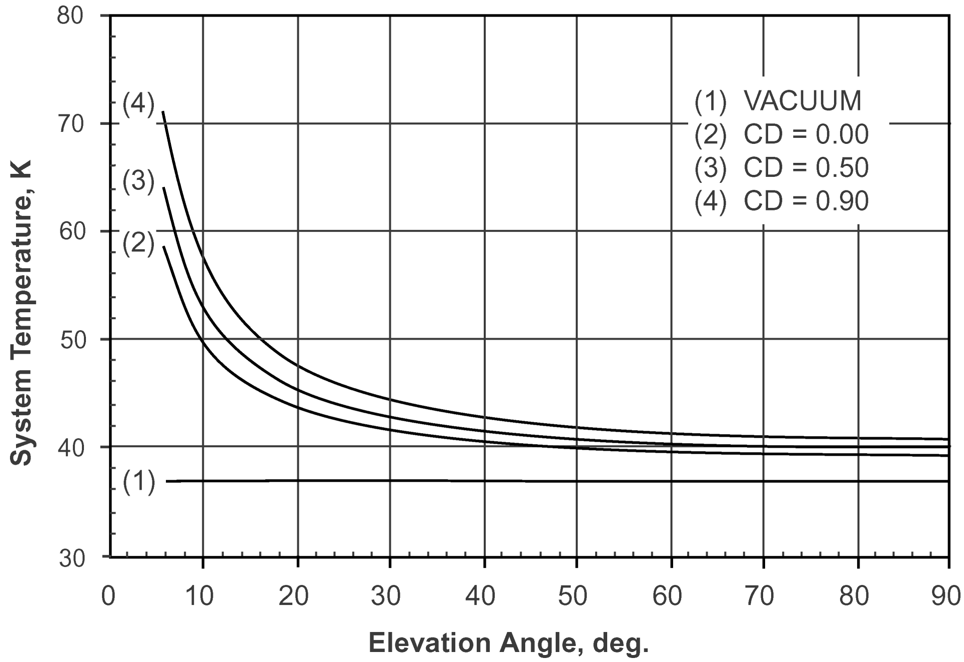


Figure 14. DSS 34 (Canberra) X-Band System Temperature Versus Elevation Angle, S/X Mode, Diplexed Path, 8420 MHz

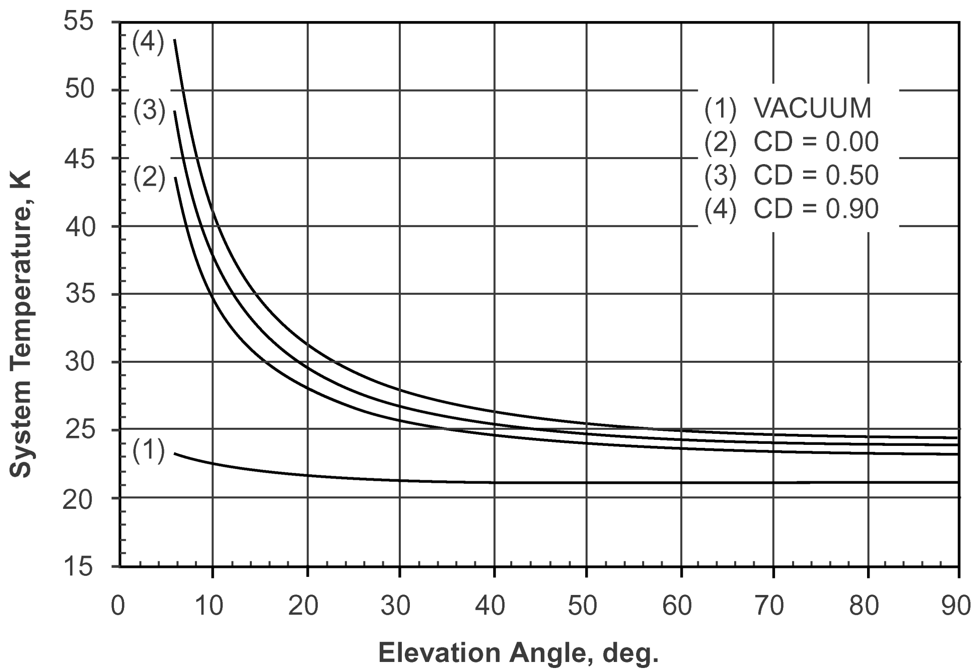


Figure 15. DSS 54 (Madrid) X-Band System Temperature Versus Elevation Angle, X-Only Mode (S/X Dichroic Retracted), Non-Diplexed Path, 8420 MHz

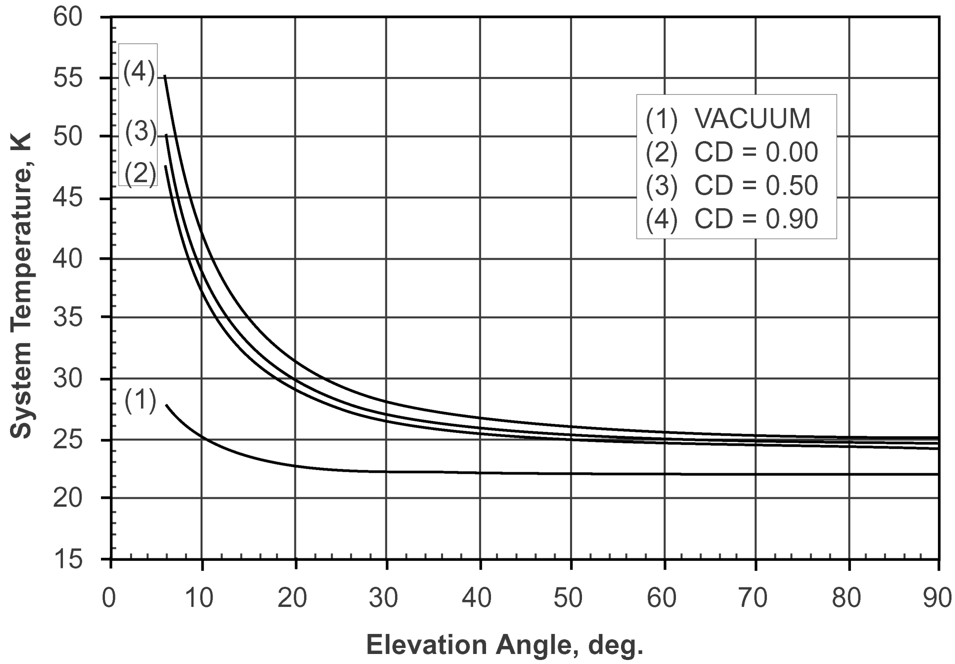


Figure 16. DSS 25 (Goldstone) X-Band System Temperature Versus Elevation Angle, Non-Diplexed Path, 8420 MHz

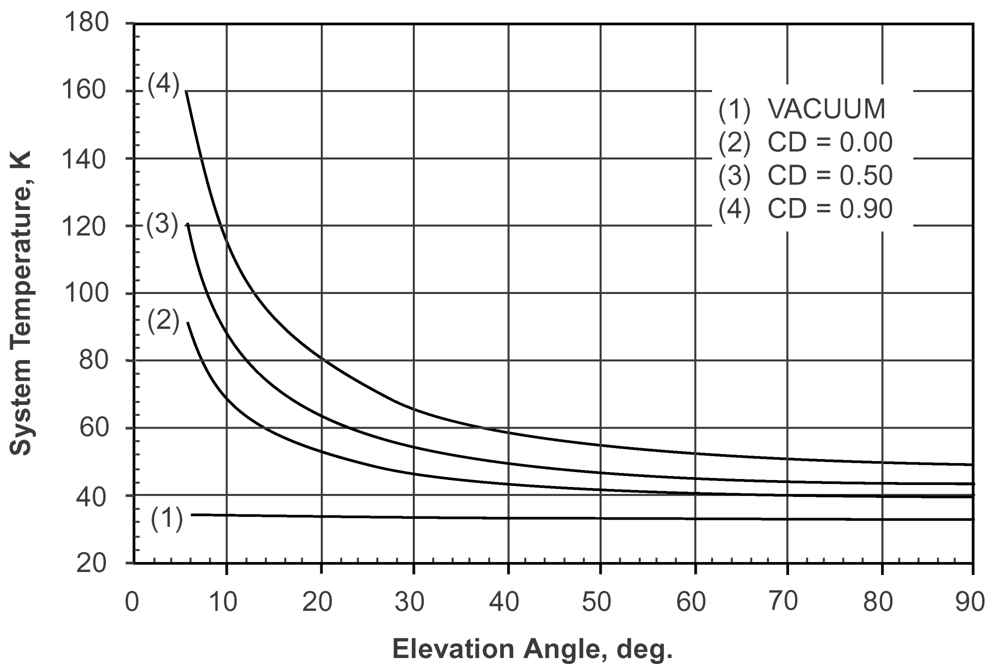


Figure 17. DSS 25 (Goldstone) Ka-Band System Temperature Versus Elevation Angle, X/Ka Mode (X/Ka Dichroic in Place), 32000 MHz

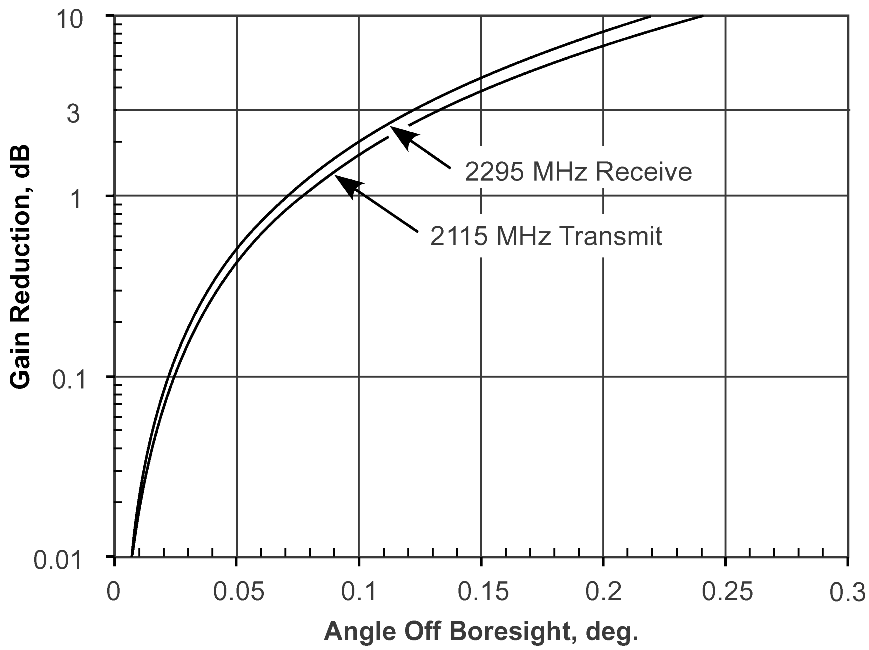


Figure 18. S-Band Gain Reduction Versus Angle off Boresight

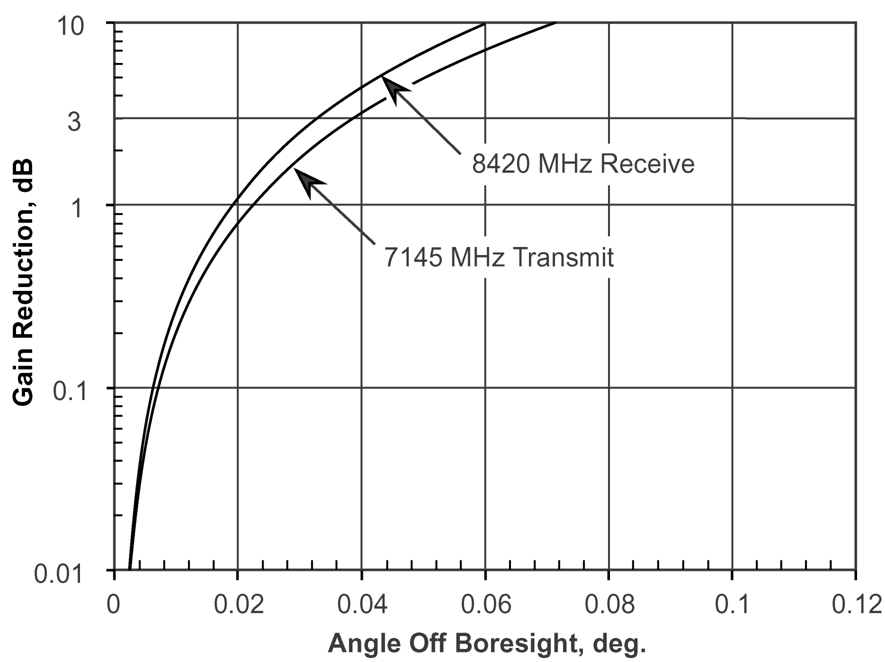


Figure 19. X-Band Gain Reduction Versus Angle off Boresight

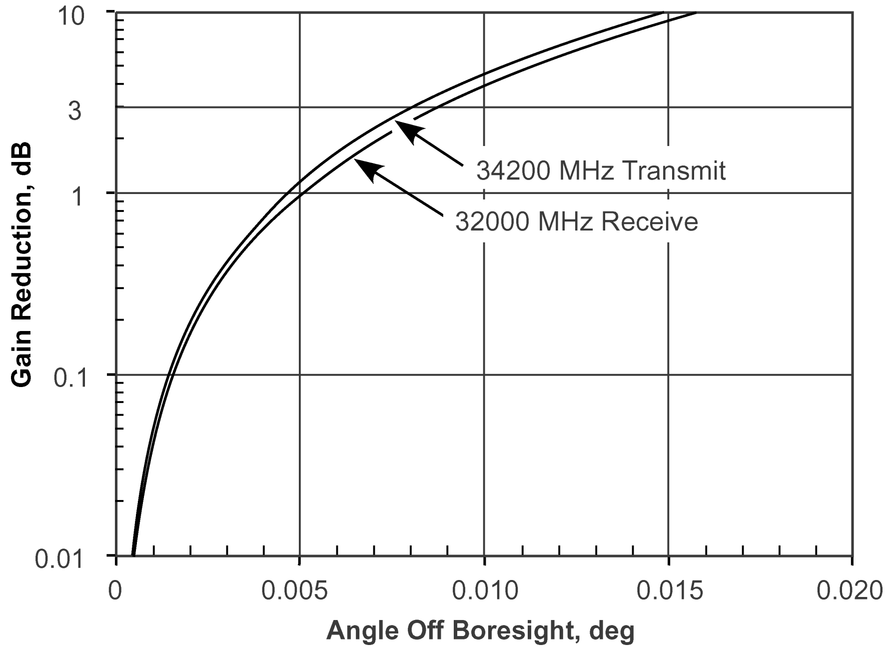


Figure 20. Ka-Band Gain Reduction Versus Angle off Boresight

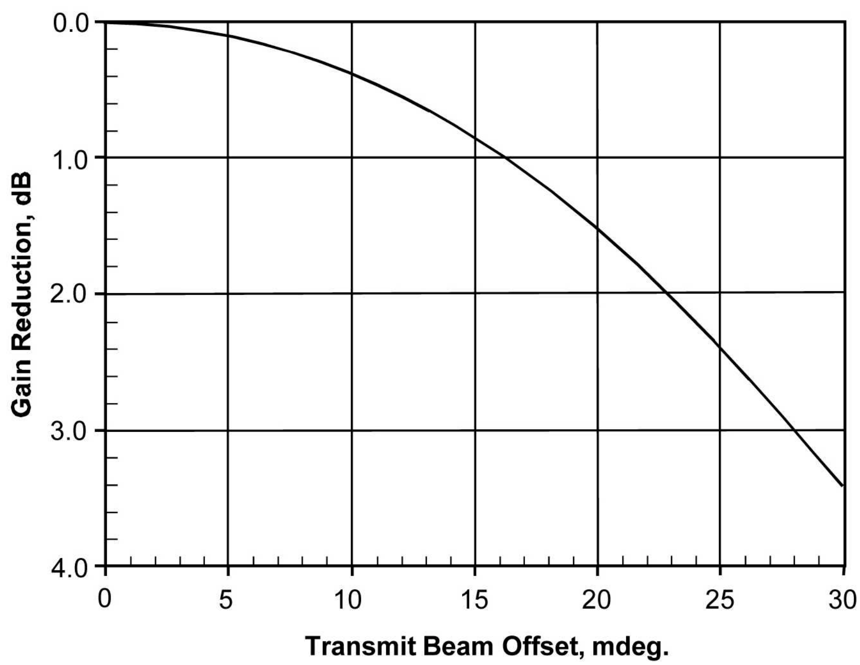


Figure 21. Ka-Band Transmit Gain Reduction Due to Aberration Correction

Appendix A
Equations for Modeling

A.1 Equations for Gain Versus Elevation Angle

The following equation can be used to generate S-, X-, and Ka-band transmit and receive gain versus elevation angle curves. Examples of these curves for selected stations and configurations are shown in Figures 6–11. See paragraph 2.1.1.1 for frequency effect modeling and module 105 for atmospheric attenuation at weather conditions other than 0%, 50%, and 90% cumulative distribution.

$$G(\theta) = G_0 - G_1(\theta - \gamma)^2 - \frac{A_{ZEN}}{\sin\theta},\ \text{dBi} \qquad \text{(A-1)}$$

where

θ = antenna elevation angle (deg.) $6 \le \theta \le 90$

G_0, G_1, γ = parameters from Tables A1, A2, and A3

A_{ZEN} = zenith atmospheric attenuation from Table A-4 or from Table 2 in module 105, dB.

A.2 Equations for System Temperature Versus Elevation Angle

The following equation can be used to generate S-, X, and Ka-band system temperature versus elevation angle curves. Examples of these curves are shown in Figures 12–17. See module 105 for atmospheric attenuation at weather conditions other than 0%, 50%, and 90% cumulative distribution..

$$T_{op}(\theta) = T_1 + T_2 e^{-a\theta} + (255 + 25CD)\left(1 - \frac{1}{10^{\frac{A_{ZEN}}{10\sin\theta}}}\right),\ \text{K} \qquad \text{(A-2)}$$

where

θ = antenna elevation angle (deg), $6 \le \theta \le 90$

T_1, T_2, a = parameters from Tables A-1, A-2, or A-3

CD = cumulative distribution used to select A_{ZEN} from Table A-4 or from Table 2 in module 105, $0 \le CD \le 0.99$

A_{ZEN} = zenith atmospheric attenuation from Table A-4 or from Table 2 in module 105, dB.

A.3 Equation for Gain Reduction Versus Pointing Error

The following equation can be used to generate gain reduction versus pointing error curves, examples of which are depicted in Figures 18, 19, and 20.

$$\Delta G(\theta) = 10 \log\left(e^{-\frac{2.773\,\theta^2}{HPBW^{\,2}}} \right), \text{dB} \tag{A-3}$$

where

θ = pointing error, deg

$HPBW$ = half-power beamwidth (from Tables 2 through 8).

A.4 Equation for Transmit Aberration Gain Reduction

The following equation can be used to generate the Ka-band transmit gain reduction curve depicted in Figure 21.

$$\Delta G(\phi) = -0.0038\phi^2 \text{, dB} \tag{A-4}$$

where

ϕ = transmit beam offset, mdeg.

Table A-1. S-Band Vacuum Gain and System Noise Temperature Parameters

Station and Configuration	Vacuum Gain Parameters				Vacuum System Noise Temperature Parameters			Figures
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 24 (Goldstone)								
S/X, Non-Diplexed (HEMT)	—	56.81	0.000032	90.0	28.34	4.7	0.05	6, 12
S/X, Diplexed (HEMT)	56.1	56.81	0.000032	90.0	34.79	4.7	0.05	
DSS 27 (Goldstone)								
S-Only, Diplexed (R/T HEMT)	54.4	55.10	0.00004	90.0	101.00	27.0	0.061	7, 13
DSS 34 (Canberra)								
S/X, Non-Diplexed (HEMT)	—	56.75	0.000037	52.5	30.68	0.0	0.0	
S/X, Diplexed (HEMT)	56.1	56.75	0.000037	52.5	39.28	0.0	0.0	
DSS 54 (Madrid)								
S/X, Non-Diplexed (HEMT)	—	56.75	0.000037	45.0	28.88	0.0	0.0	
S/X, Diplexed (HEMT)	56.1	56.75	0.000037	45.0	37.48	0.0	0.0	

Notes:

† G_0 values are nominal at the frequency specified in Tables 2, 3, 6, or 8. Other parameters apply to all frequencies within the same band.

Table A-2. X-Band Vacuum Gain and System Noise Temperature Parameters

Station and Configuration	Vacuum Gain Parameters				Vacuum System Noise Temperature Parameters			Figures
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 24 (Goldstone)								
X-Only, Non-Diplexed (MASER)	—	68.11	0.000027	51.5	23.18	0.0	0.0	
S/X, Non-Diplexed (MASER)	—	68.06	0.000027	51.5	24.58	0.0	0.0	
DSS 25 (Goldstone)								
X/Ka, Non-Diplexed (MASER)	—	68.37	0.000028	47.5	22.13	14.0	0.15	10, 16
X/Ka, Non-Diplexed (HEMT)	—	68.37	0.000028	47.5	35.93	14.0	0.15	
X/Ka, Diplexed (MASER)	67.1	68.37	0.000028	47.5	29.63	14.0	0.15	
X/Ka, Diplexed (HEMT)	67.1	68.37	0.000028	47.5	43.43	14.0	0.15	
DSS 26 (Goldstone)								
X-Only, Diplexed (HEMT-1)	67.1	68.29	0.000028	45.0	25.8	4.5	0.08	
X-Only, Diplexed (HEMT-2)	67.1	68.29	0.000028	45.0	26.5	4.5	0.08	

Notes:

† G_0 values are nominal at the frequency specified in Tables 4, 6, and 7. Other parameters apply to all frequencies within the same band.

Table A-2. X-Band Vacuum Gain and System Noise Temperature Parameters (Continued)

Station and Configuration	Vacuum Gain Parameters				Vacuum System Noise Temperature Parameters			Figures
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 34 (Canberra)								
X-Only, Non-Diplexed (HEMT)	—	68.29	0.000023	47.5	28.00	0.0	0.0	
X-Only, Diplexed (HEMT)	67.1	68.29	0.000023	47.5	35.50	0.0	0.0	
S/X, Non-Diplexed (HEMT)	—	68.24	0.000023	47.5	29.70	0.0	0.0	
S/X, Diplexed (HEMT)	67.1	68.24	0.000023	47.5	37.20	0.0	0.0	8, 14
DSS 54 (Madrid)								
X-Only, Non-Diplexed (MASER)	—	68.29	0.000023	47.5	21.07	4.0	0.1	9, 15
X-Only, Diplexed (MASER)	67.1	68.29	0.000023	47.5	28.62	4.0	0.1	
S/X, Non-Diplexed (MASER)	—	68.24	0.000023	47.5	22.82	4.0	0.1	
S/X, Diplexed (MASER)	67.1	68.24	0.000023	47.5	30.22	4.0	0.1	

Notes:

† G_0 values are nominal at the frequency specified in Tables 4, 6, and 7. Other parameters apply to all frequencies within the same band.

Table A-3. Ka-Band Vacuum Gain and System Noise Temperature Parameters

Station and Configuration	Vacuum Gain Parameters				Vacuum System Noise Temperature Parameters			Figures
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 25 (Goldstone)								
Ka-Only, Diplex (HEMT)	79.5	78.98	0.00052	45.0	28.41	2.9	0.013	
X/Ka, Diplex (HEMT)	79.5	78.83	0.00052	45.0	31.91	2.9	0.013	11, 17

Notes:

† G_0 values are nominal at the frequency specified in Tables 5 and 7. Other parameters apply to all frequencies within the same band.

Table A-4. S-, X-, and Ka-Band Zenith Atmospheric Attenuation (A_{ZEN})

Station	A_{ZEN}, dB*		
	CD† = 0.00	CD† = 0.50	CD† = 0.90
S-Band			
Goldstone	0.033	0.032	0.031
Canberra	0.036	0.035	0.034
Madrid	0.034	0.033	0.033
X-Band			
Goldstone	0.037	0.040	0.047
Canberra	0.040	0.048	0.059
Madrid	0.038	0.045	0.053
Ka-Band			
Goldstone	0.116	0.177	0.274

Notes:

* From Table 2 in module 105,

† CD = cumulative distribution.